Choptank River Basin Summary

Final Version for 1985-2002 Data
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Choptank Basin Characteristics

The Choptank River basin, at 795 square miles, is the smallest of the seven Chesapeake Bay tributary basins monitored by the River Input Monitoring Program. About 700 square miles of land in Maryland are drained by the Choptank, including portions of Caroline, Dorchester, Queen Anne's and Talbot Counties. The river originates in Kent County, Delaware, and flows southwest, quickly becoming tidally controlled near Greensboro, Maryland. Larger waterbodies in this basin include the Choptank, Little Choptank, and Tred Avon Rivers and Broad, Harris, and Tuckahoe Creeks. The basin is located solely within the Coastal Plain physiographic province.

The 2000 census population for the Maryland portion of the Choptank basin was 71,000. Cambridge, Maryland, with a population of 11,000, is the largest city in this basin.

The Choptank basin is 58 percent agricultural, 33 percent forested, and nine percent urban. "With its preponderance of poorly draining soils and forest area, this basin is atypical compared to much of the Eastern Shore. Much of the Choptank River Basin is drained through ditches that have been installed over many decades to drain the flatlands for agriculture use. The drains are typically kept clear of vegetation, thus expediting flow and providing less opportunity for nutrient uptake and denitrification." From *Factors Affecting Nutrient Trends in Major Rivers of the Chesapeake Bay Watershed,* Sprague et al., 2000.

The dominant characteristic of the Choptank basin is agricultural land use. As a result, the major issues in the basin are those of non-point source nutrient and sediment loads. A wide array of best management practices have been planned to reduce impacts of non-point sources. Thus far, BMP implementation has been achieved with mixed results. In some cases, such as shore erosion controls, forest conservation, forest buffers, and nutrient management plans, the goals set in the Choptank Tributary Strategy have nearly been met or have been exceeded. For other BMPs, notably those dealing with stormwater management, implementation is falling short of the Tributary Strategy goals.

The majority of the housing in the basin is in either rural or farm settings. Sewage disposal in the Choptank is split nearly evenly between septic systems and municipal sewage systems.

As of 2002, the largest contributor of nitrogen in the Choptank basin was agriculture (73 percent). Following that were point sources and urban (eight percent and six percent, respectively). Agriculture was also the largest source of phosphorus (67 percent) followed by mixed open lands (12 percent), point sources (12 percent), and urban sources (eight percent). Only 14 percent of the nitrogen and 1.9 percent of the phosphorus generated within the basin reaches the river input station (Sprague et al, 2000). The dominant contributor of sediment loads is agriculture (87 percent).

Figure CH1 – 2000 Land Use in the Choptank River Basin

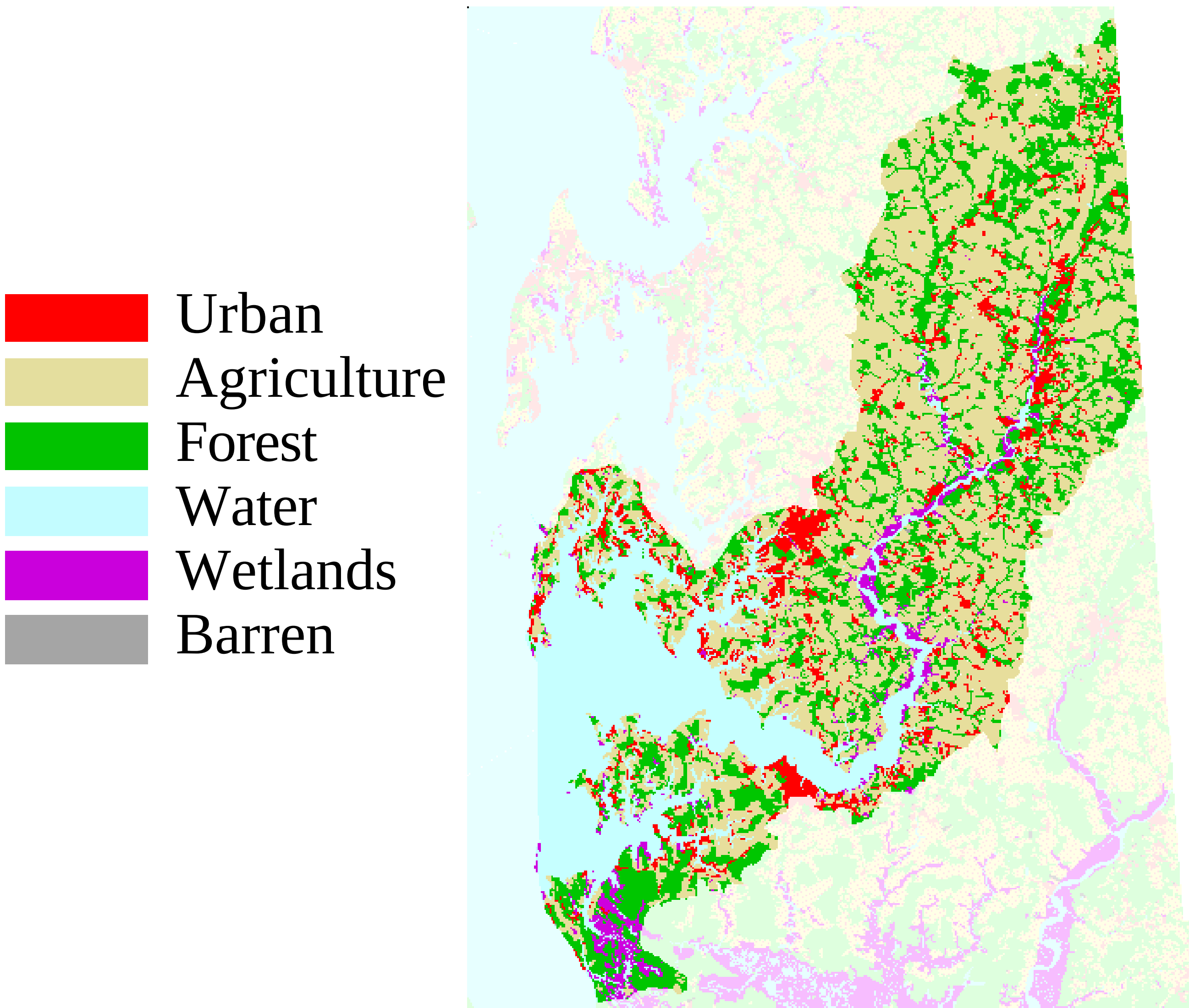
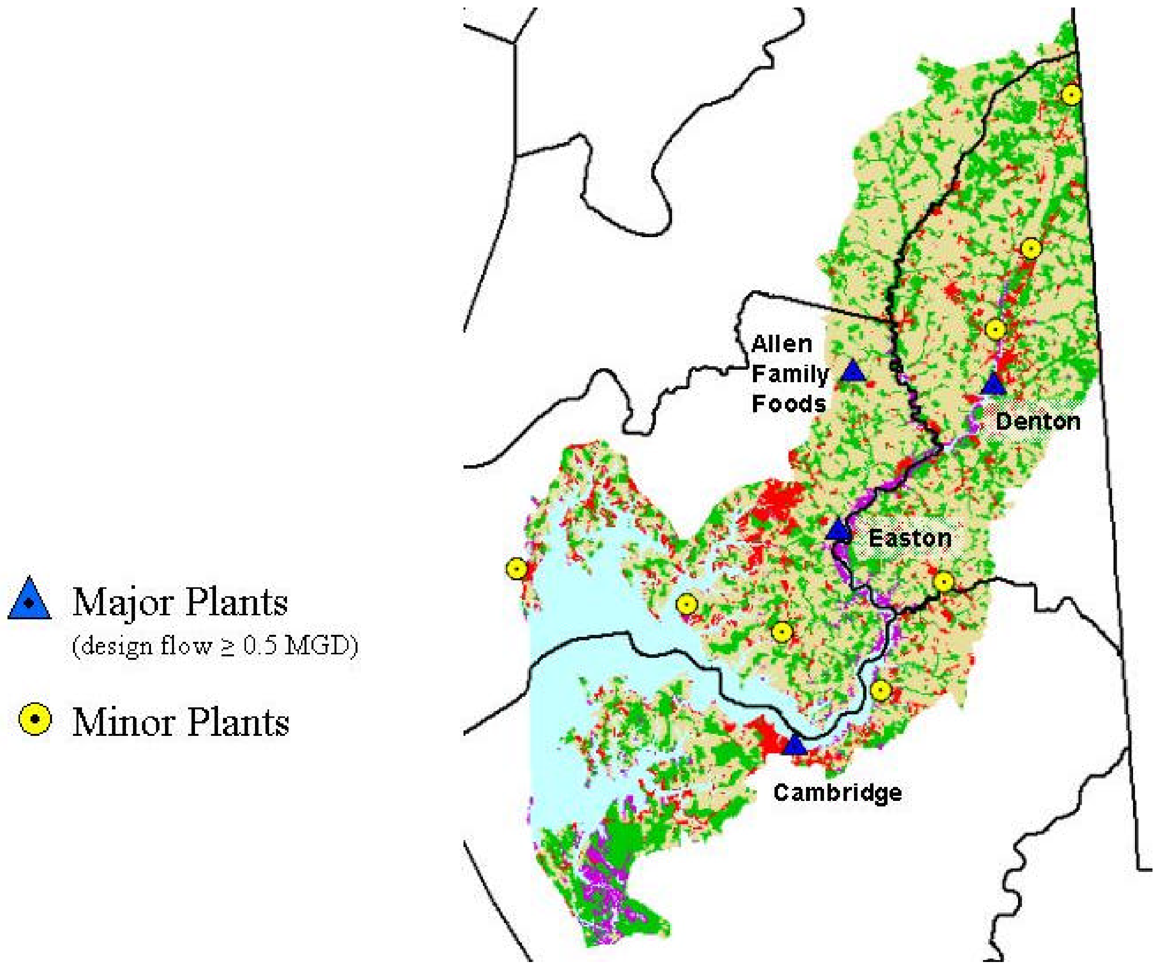


Figure CH2 – Wastewater Treatment Plants in the Choptank River Basin

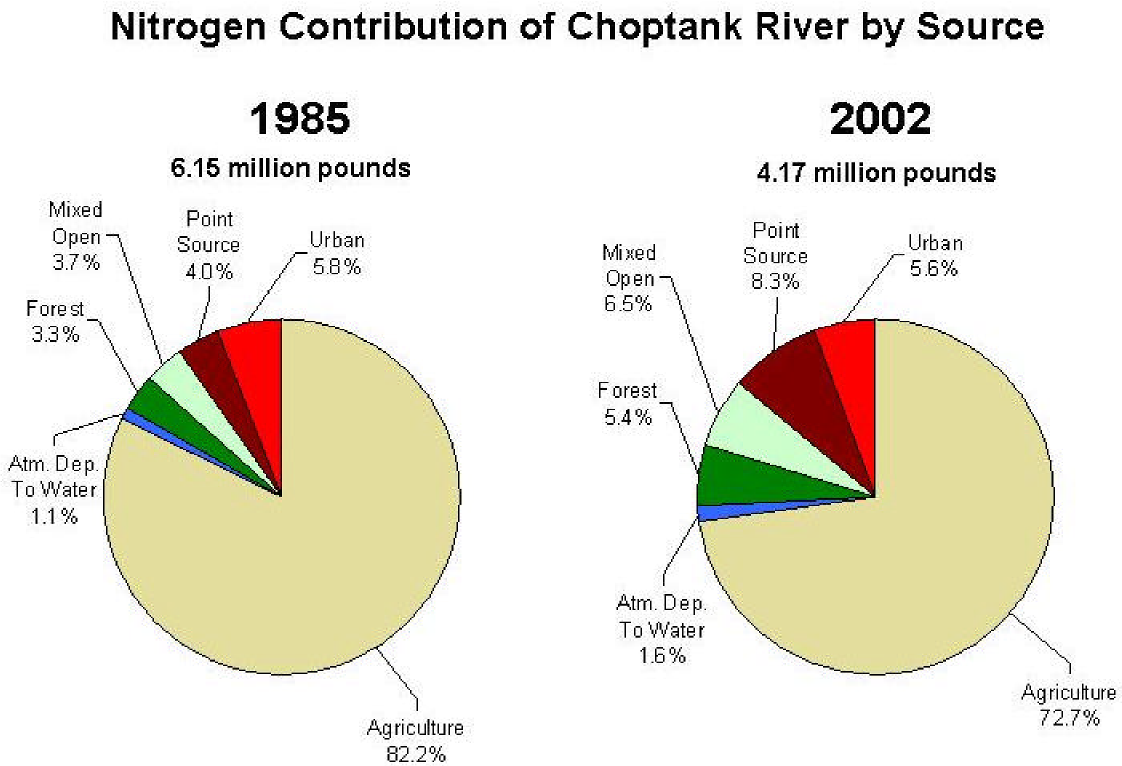


The Choptank is somewhat unique among the major Chesapeake river systems in that it doesn't have a true fall line and that the mesohaline portion of the river has been divided into two segments. The downstream mesohaline segment is actually an embayment and conditions within it are more representative of conditions within the mainstem bay.

The river input station near Greensboro (01491000) receives drainage from 14 percent of the watershed. Of the nine rivers monitored by the river input program, the Choptank River contributes less than one percent of the streamflow, the total nitrogen load, and the total phosphorus load to Chesapeake Bay (Belval and Sprague, 1999).

The basin supports over 80 species of fish in its freshwater streams and brackish waters, including striped bass, largemouth bass, and flounder. The lower portion of the watershed is an important concentration area for waterfowl.

Figure CH3 – 1985 and 2002 Nitrogen Contribution to the Choptank River Basin by Source.



Source: Chesapeake Bay Program Phase 4.3 Watershed Model

Figure CH4 – 1985 and 2002 Phosphorus Contribution to the Choptank River Basin by Source.

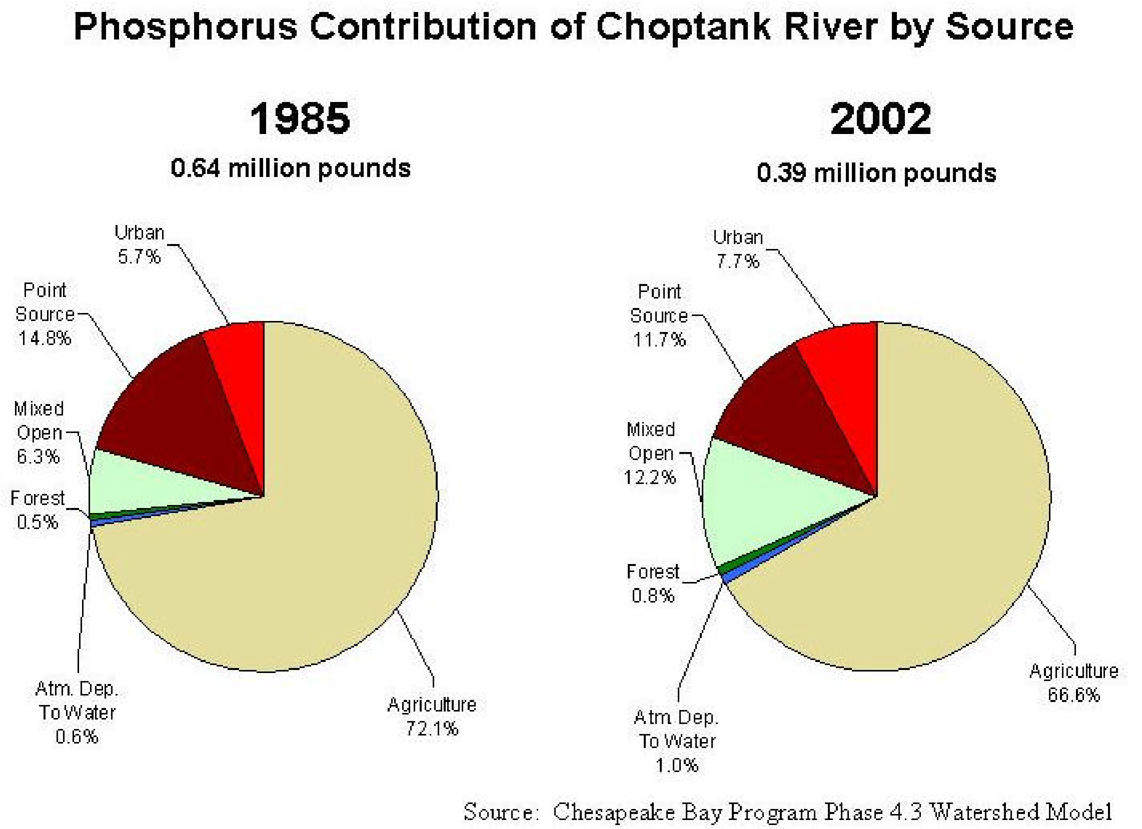
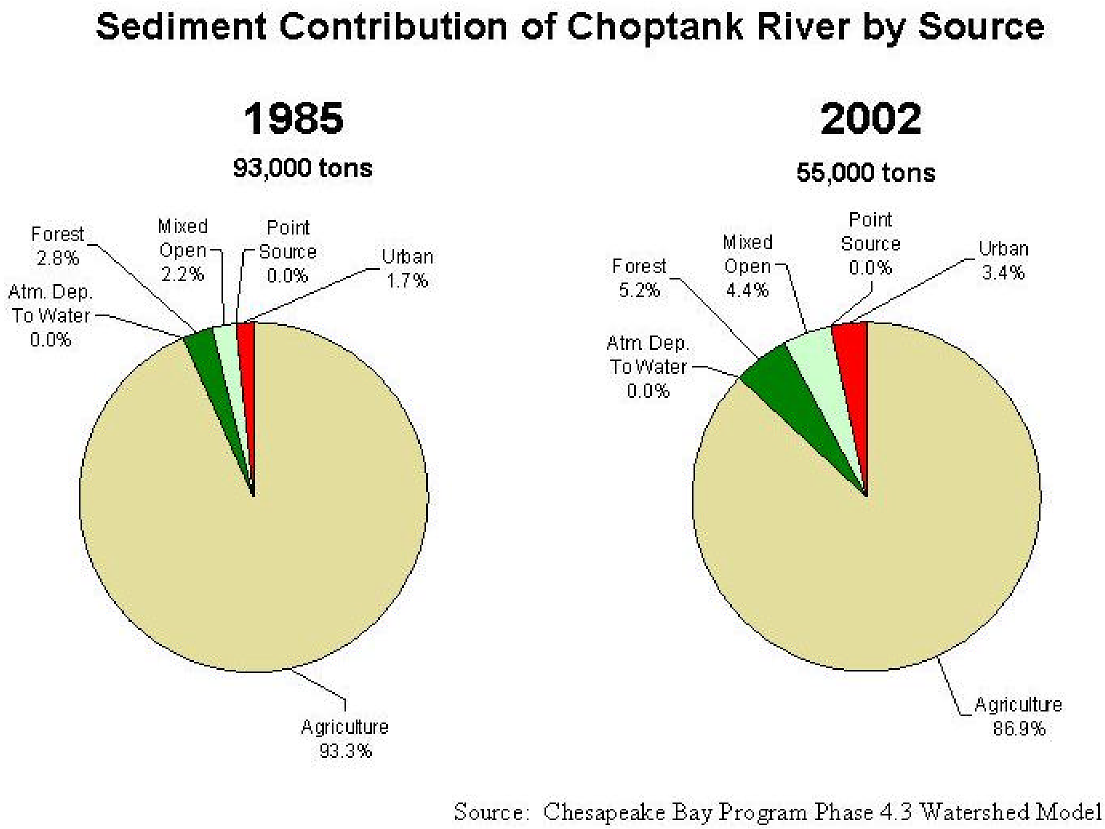


Figure CH5 – 1985 and 2002 Sediment Contribution to the Choptank River Basin by Source.



Overview of Monitoring Results

Water discharge at the river input site (Greensboro, MD, USGS station 014910000) increased over the period 1985-2000. However, this is an artifact caused by the start of the Bay Program monitoring during a relatively dry period. The total available record of discharge shows that discharge has fluctuated considerably over the last 50 years, but there are no long-term trends (Figure CH6). However, river discharge is an important driver of water quality in the estuary, and the increasing discharge over the 1985 – 1999 monitoring period tends to induce interannual trends in other parameters at the estuarine stations described below.

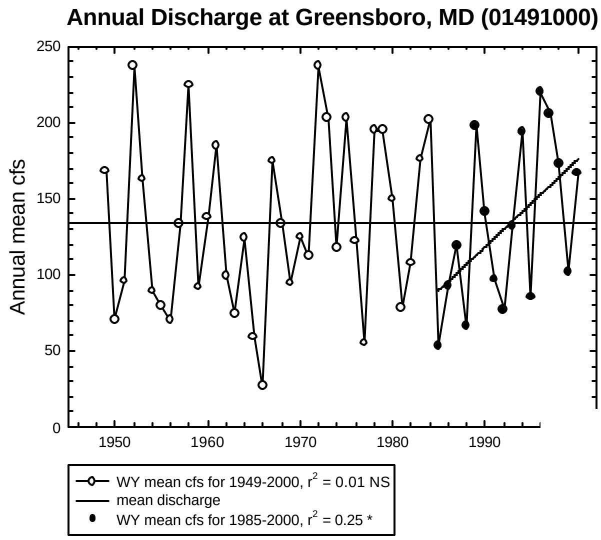


Figure CH6 – Annual average discharge at the USGS gauging station on the Choptank River. From Tom Fisher, University of Maryland.

Nitrate concentrations at the river input site showed a clear increasing trend, particularly when all available data are considered (Figure CH7). There are fewer total nitrogen data available, but nitrate represents ~75% of total nitrogen at this station. Therefore, the nitrate trend is indicative of increasing inputs of nitrogen from diffuse sources, probably fertilizer applications on agricultural fields and septic system drainage from urban areas. This is at variance with some modeling studies, but these are the observed trends from the monitoring data. There is no evidence for improving water quality at this station.

Wastewater discharges of nitrogen and P to the Choptank have remained relatively stable since 1984. At the two largest plants (Easton and Cambridge,

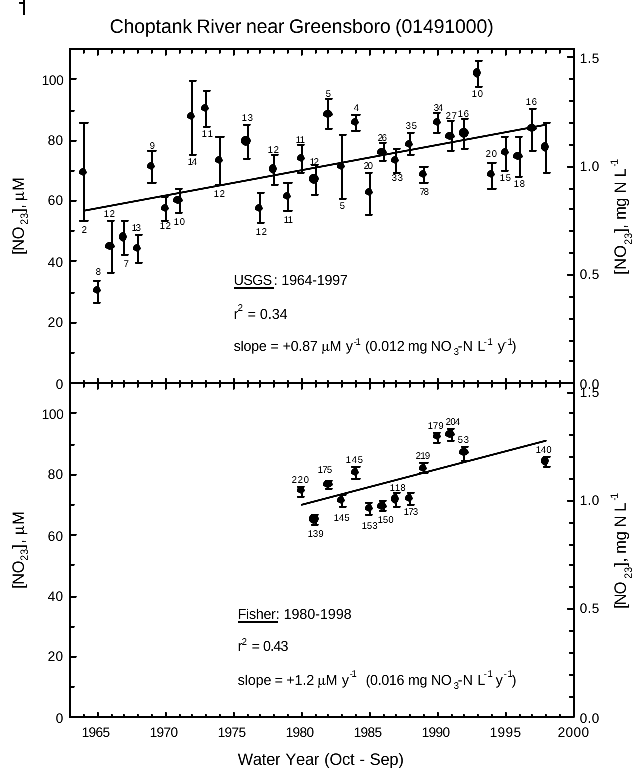


Figure CH6 – Historical trends in nitrite+nitrate concentrations (NO23) at the USGS gauging station in the Choptank River basin near Greensboro, Maryland in two independently collected datasets. The upper panel are data from annual USGS Water Resources Reports, and the bottom panel is from Fisher et al. (1998) and Fisher (unpub.). Numbers above or below points are the numbers of samples averaged to compute the mean and standard errors.

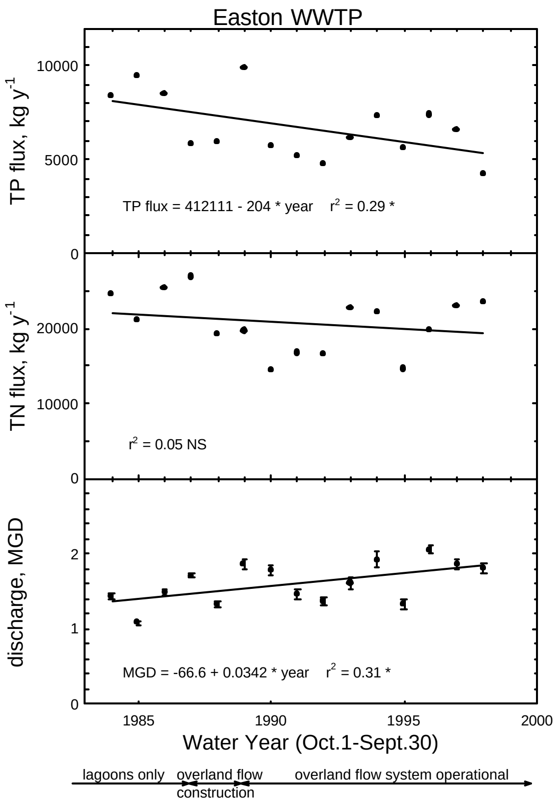


Figure CH8 – Annual average discharge and mass flux of N and P from the Easton Waste Water Treatment Plant to the Choptank

representing five of the total of six million gallons per day in the basin), the volume of inputs have increased due to population growth, but water quality efforts at the two plants have resulted in decreasing concentrations of nitrogen and phosphorus in effluent. This has resulted in decreasing phosphorus mass fluxes from the Easton plant, and stable fluxes of nitrogen from Easton and nitrogen and phosphorus from Cambridge, despite the increasing volume.

Water quality at the three estuarine monitoring stations exhibited varying patterns of physical and biological control. At the oligohaline ET5.1, temperature and freshwater discharge controlled both seasonal and interannual variations in concentrations of nitrogen, phosphorus, chlorophyll a, and salinity. total nitrogen and nitrate concentrations were significantly correlated with discharge, and both total nitrogen and nitrate tended to increase at this station over 1985-1999, consistent with the data in Figures CH6 and CH7. However, interannual variability in discharge obscured the significance of the increases. The only significant interannual trend at station ET5.1 was a small annual increase in Secchi, indicative of slowly improving water clarity. However, water at this station is turbid and nutrient-rich, and algal growth is controlled primarily by physical factors such as light availability, water residence time, temperature, and discharge. The improving light climate, as indicated by the small interannual increases in Secchi depth, will tend to allow algal biomass to increase over time at this station. Despite improving water clarity, the status of all water quality parameters was "poor," and bay grass habitat requirements were not met for chlorophyll, total suspended solids and Secchi.

At the mesohaline station ET5.2, there was evidence of degrading water quality. Over the monitoring period of the Bay Program, 1985-1999, chlorophyll *a* and total suspended solids have approximately doubled, and Secchi depth has decreased from ~1.5 to <1 m (Figure CH9). Seasonal and interannual trends at this station reflect the effects of watershed inputs, mixing with Bay water, as well as in situ biological processes. Average nitrogen and P concentrations show little tendency to change interannually, although the efficiency of biological conversion of nitrogen and phosphorus inputs into plankton is increasing (Figure CH9). The decreasing water quality trends at this station are influenced by the significant increase in discharge over the monitoring period of the Bay Program (Figure CH7), and flow-adjusted data tend to show no significant trends or slight decreases in phosphorus concentrations. However, it is clear that there is little observed improvement in water quality in the monitoring data for these stations and that the goals of the monitoring program are not being achieved.

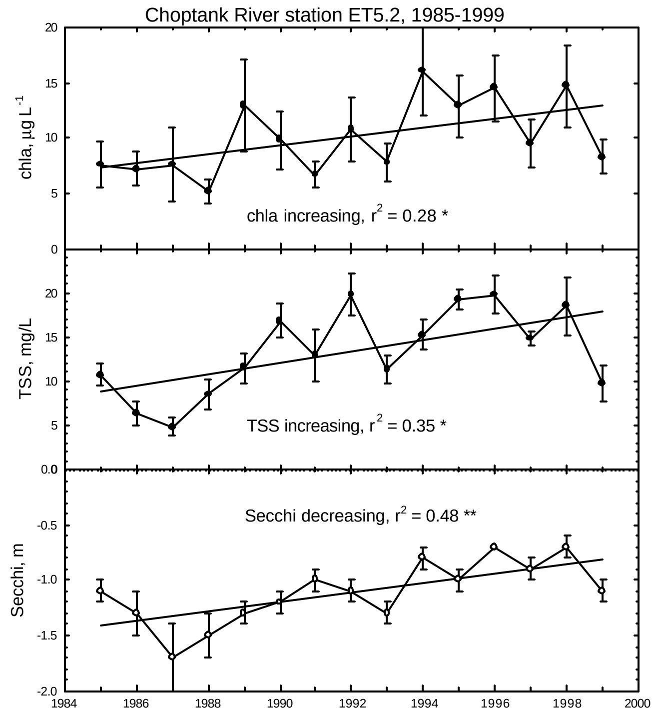


Figure CH9 – Chlorophyll, total suspended solids and Secchi trends in the Choptank indicative of degrading water quality at station ET5.2.

Other phytoplankton parameters were also degrading. Phytoplankton cell counts indicate that the community is shifting to one comprised of smaller cells including cyanobacteria (blue-green algae) and dinoflagellates. This shift to smaller cell sizes of less desirable algal types has been detected in many areas of the Chesapeake. This process is of concern because smaller cells, and particularly blue-green algae, are not a good food source for filter feeders.

In spite of the degrading phytoplankton trends, zooplankton and benthic biomass and abundance were improving throughout the Choptank. The Striped Bass food availability index, which is based upon zooplankton densities, increased by 250% or more over the period of record (1985-1999). Therefore, although the food source for zooplankton (phytoplankton) appears to be degrading, zooplankton and benthos are unaffected at this point, probably because of the abundant food supply and good dissolved oxygen in bottom waters.

Water and Habitat Quality

Non-tidal Water Quality Monitoring Information Sources

Much useful information on non-tidal water quality is available on the Internet. The State of Maryland's Biological Stream Survey (MBSS) basin fact sheets and basin summaries are available at:
http://www.dnr.state.md.us/streams/mbss/mbss_fs_table.html
MBSS also reports stream quality information summarized by county at:
http://www.dnr.state.md.us/streams/mbss/county_pubs.html In addition to these reports and fact sheets, detailed and more recent information and data are also available on the MBSS website: **http://www.dnr.state.md.us/streams/mbss**

Water quality information collected by Maryland's volunteer Stream Waders is available at: **http://www.dnr.state.md.us/streams/mbss/mbss_volun.html**

Long-term Tidal Water Quality Monitoring

Good water quality is essential to support the animals and plants that live or feed in the Choptank and its tributaries. Important water quality parameters are measured at two long-term tidal monitoring stations and five long-term nontidal monitoring stations in the Choptank basin. Parameters measured include nutrients, water clarity (Secchi depth), dissolved oxygen, total suspended solids, and algal abundance.

Current status is determined based on the most recent three-year period (2000-2002). For dissolved oxygen, the current are compared to ecologically meaningful thresholds to assign a status of good, fair, or poor. Thresholds have not been established for the other parameters, so the current data are compared to a baseline data set, and assigned a status of good, fair, or poor, which is only a *relative* status compared to the baseline data. Trends are determined using a non-parametric test for trend (the Seasonal Kendall test). For a detailed description of the methods used to determine status and trends, see http://www.dnr.state.md.us/bay/tribstrat/status_trends_methods.html**.**

Total nitrogen decreased somewhat at the Outer and Little Choptank stations during the period from 1985 to 2002. Total phosphorus decreased at the Outer Choptank, Little Choptank, and Ganey Wharf stations, but increased somewhat at the Red Bridges station. Algal abundance and total suspended solids increased significantly at the US Route 50 station and somewhat at the Outer Choptank station. Total suspended solids levels decreased at the Outer Choptank and Little Choptank stations, but water clarity worsened at these stations. Dissolved oxygen levels are good at the Outer Choptank station but poor at the Little Choptank station; they worsened at both of these stations from 1985 to 2002.

Figure CH10 – Total Nitrogen Concentrations in the Choptank River Basin

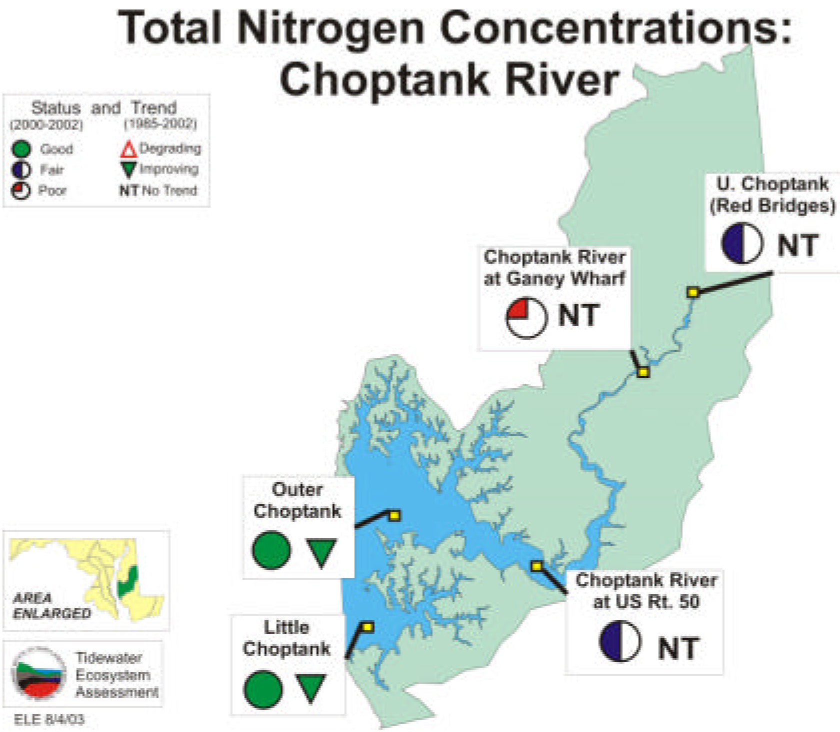


Figure CH11 – Total Phosphorus Concentrations in the Choptank River Basin

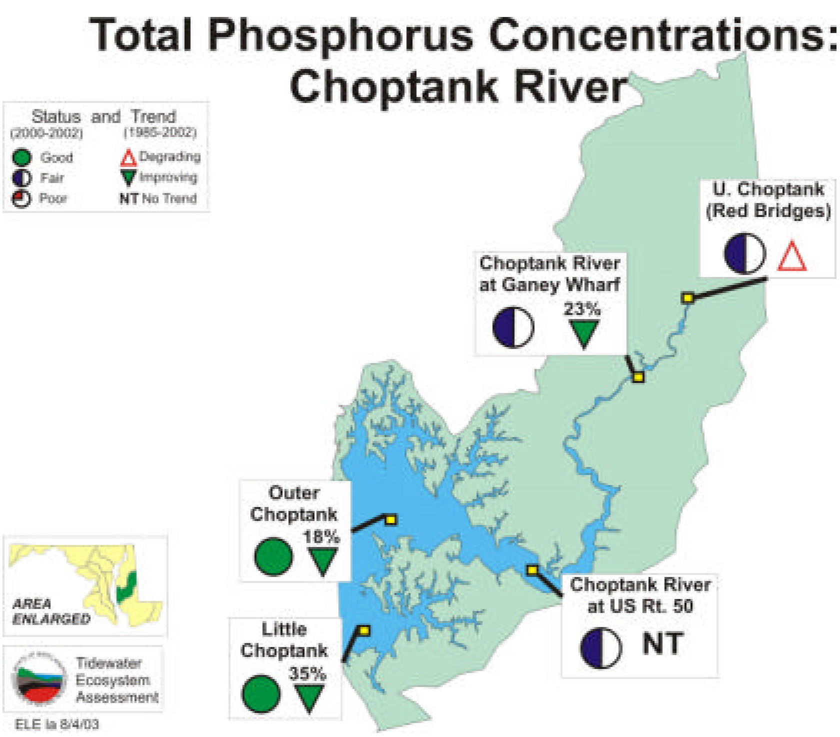


Figure CH12 – Abundance of Algae in the Choptank River Basin

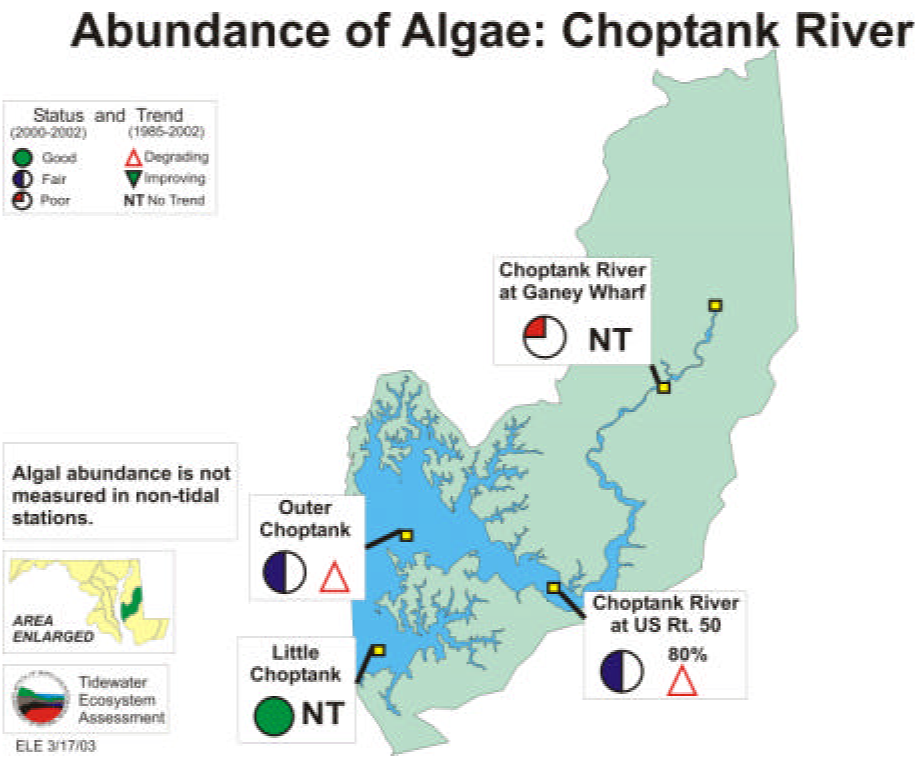


Figure CH13 – Total Suspended Solids Concentrations in the Choptank River Basin

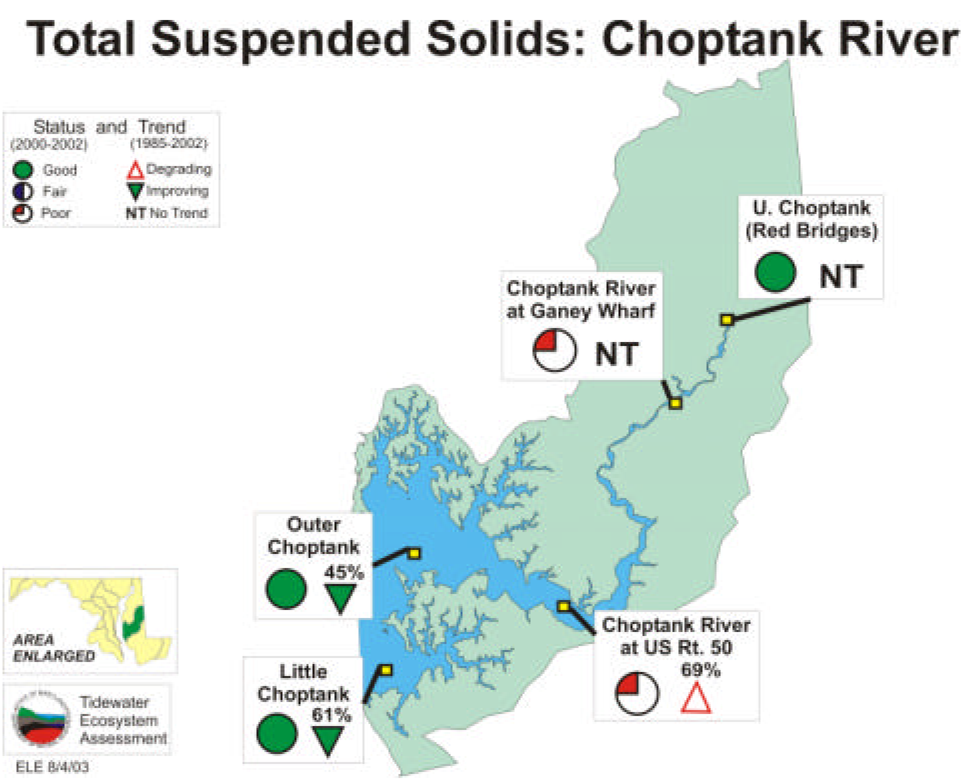


Figure CH14 – Water Clarity (Secchi Depth) in the Choptank River Basin

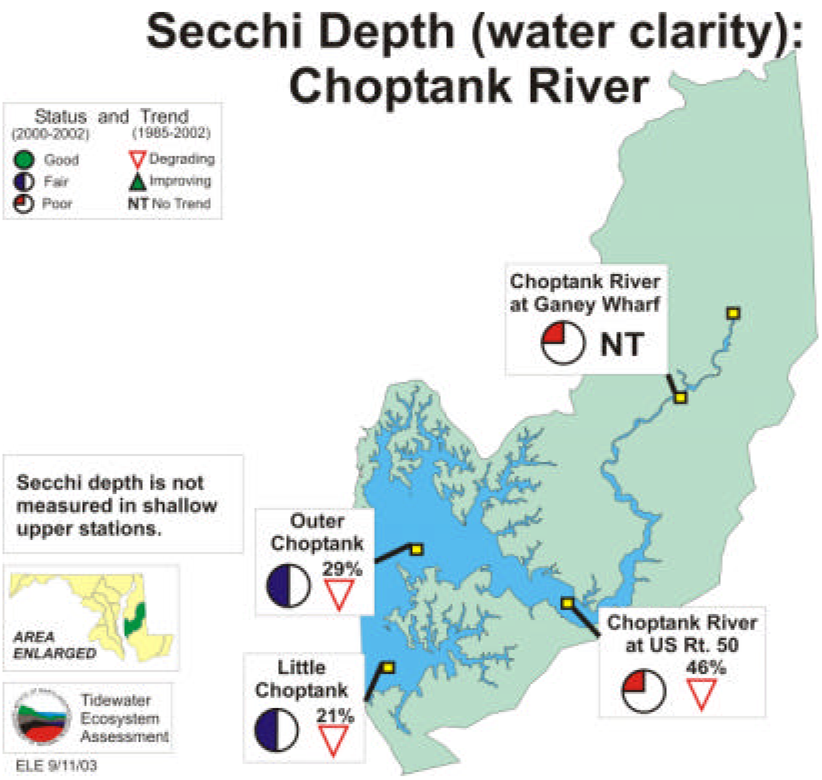
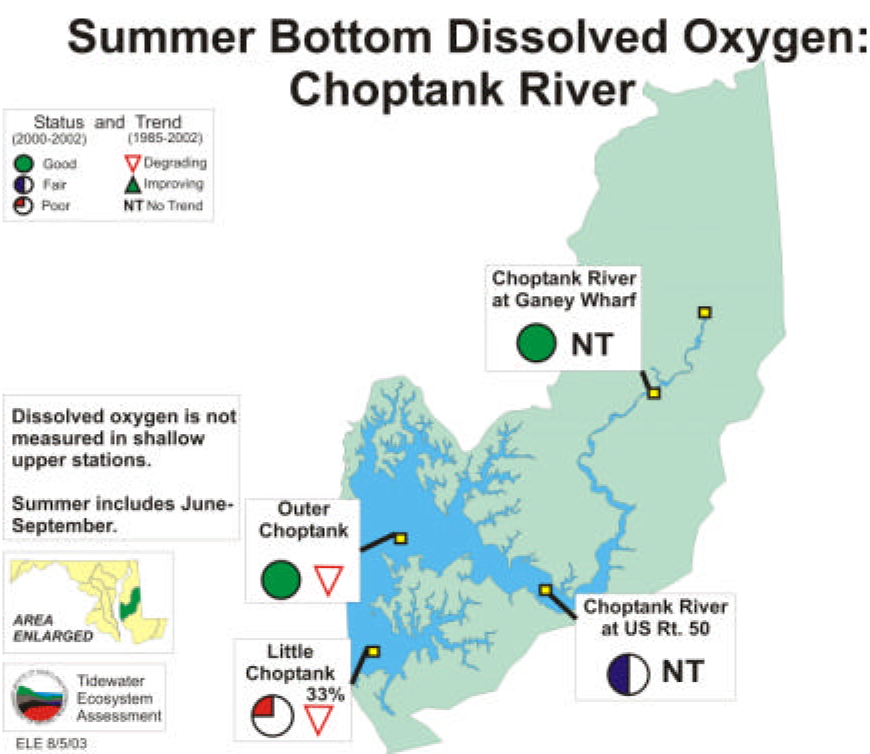


Figure CH15 – Dissolved Oxygen in the Choptank River Basin



SAV (Bay Grasses)

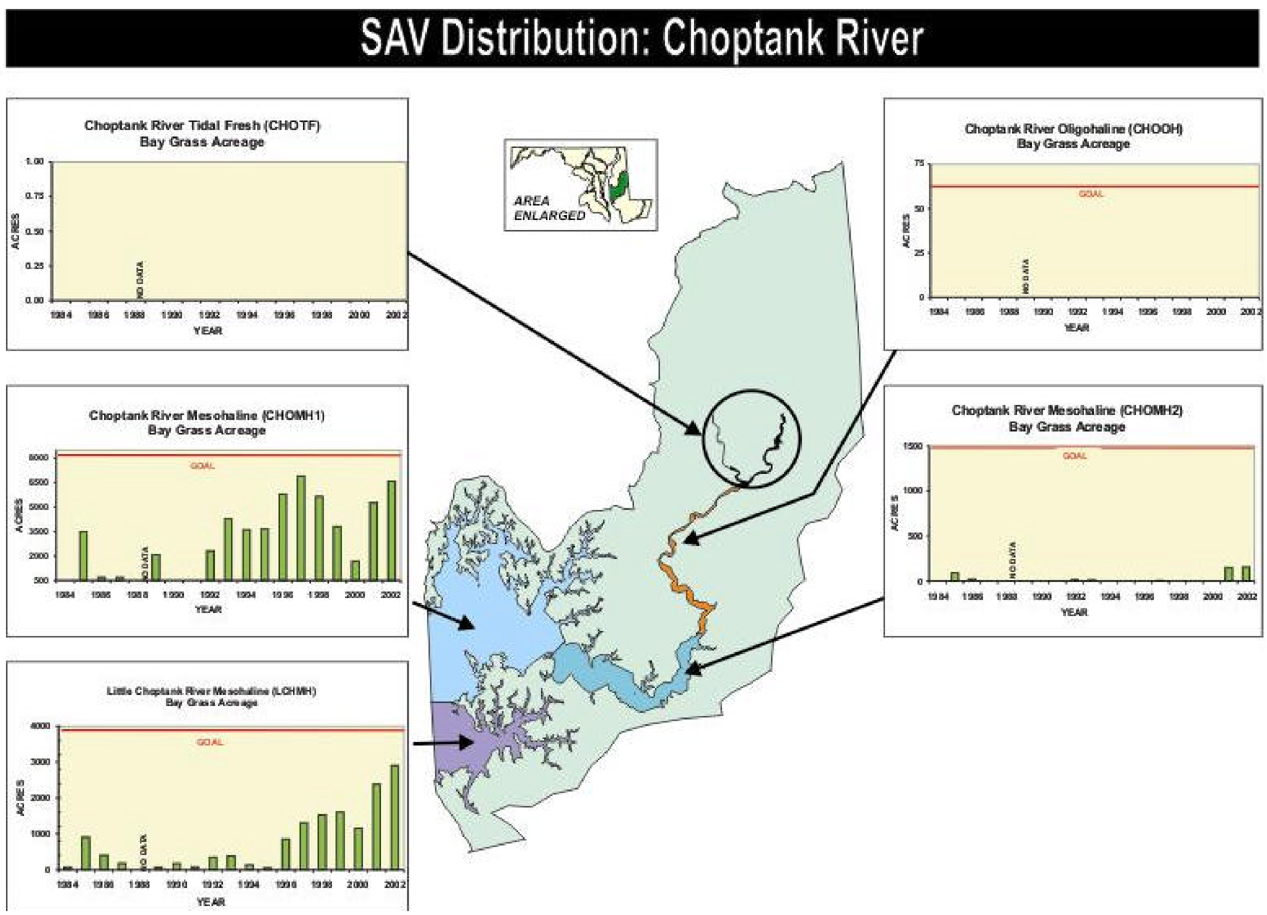
The well-defined linkage between water quality and submerged aquatic vegetation (SAV) distribution and abundance make SAV communities good barometers of the health of estuarine ecosystems. SAV is important not only as an indicator of water quality, but it is also a critical nursery habitat for many estuarine species. Blue crab post-larvae are 30 times more abundant in SAV beds than adjacent unvegetated areas. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region.

The Chesapeake Bay Program has developed new criteria for determining SAV habitat suitability of an area based on water quality. The APercent Light at Leaf@ habitat requirement assesses the amount of available light reaching the leaf surface of SAV after being attenuated in the water column and by epiphytic growth on the leaves themselves. The document describing this new model is found on the Chesapeake Bay Program website (www.chesapeakebay.net/pubs/sav/index.html). The older AHabitat Requirements@ of five water quality parameters are still used for diagnostic purposes. Re-establishment of SAV is measured against the ATier 1 Goal@, an effort to restore SAV to any areas known to contain SAV from 1971 to 1990.

SAV has never been reported in the tidal fresh and oligohaline regions (above Bow Knee Point) of the Choptank River (Figure CH16). In 1999 and 2000, experimental transplants of wild celery were performed at Martinak State Park, near Denton (see www.dnr.state.md.us/bay/sav/martinak.html). These transplants did not thrive, due to poor water quality and heavy grazing. Very small amounts of SAV have been mapped by the Virginia Institute of Marine Science (VIMS) aerial survey (www.vims.edu/bio/sav/) in the area extending from Bow Knee Point to Castle Haven Point (mesohaline region), well below the Tier I goal (Figure CH16). Ground-truthing by citizen volunteers in the Bow Knee Point and Chancellor Point areas has found horned pondweed, an early season species typically missed by the summer aerial survey. Patterns of SAV distribution match those in the water quality data for these areas. Monitoring station data from Ganey Wharf indicate that none of the SAV habitat criteria are met, though levels of algae are borderline. Data from the station at the U.S. Route 50 bridge indicate that levels of total suspended solids and algae pass the habitat requirement. Percent light at leaf, nitrogen and phosphorous levels are borderline. Light attenuation fails in this region.

For the Outer Choptank and Little Choptank Rivers (mesohaline areas), there are very different conditions. The Outer Choptank River has generally shown increasing SAV distribution since 1991 (Figure CH16). However, the data from 1998, 1999 and 2000 indicate that abundance has declined substantially from the peak in 1997, when SAV coverage almost reached the Tier I goal of 7,400 acres. The drop in acreage in 2000 is the most dramatic, probably due to severe algae blooms that impacted much of the Chesapeake Bay mesohaline areas. However, in 2001, SAV rebounded to 5,260 acres (72 percent of the Tier I goal). SAV beds are found fringing much of the shoreline downstream of Chlora and Castle Haven Points. For the Little Choptank River, SAV distribution was highly variable until 1995 (Figure CH16). After that time, SAV coverage has dramatically increased, exceeding the Tier I goal in 1998, 1999 and 2001, where there was 2,379 acres or 156% of the goal. Most of the beds are found fringing the northern shoreline of the river, while the southern shoreline has fewer beds. Ground-truthing data indicates that the dominant species (in order of the number of occurrence) are widgeon grass, horned pondweed and sago pondweed. Both of these regions have very good water quality, with percent light at leaf, light attenuation, suspended solids, algae and phosphorous levels passing the SAV habitat requirement. Nitrogen levels are borderline.

Figure CH16 –Bay Grasses (Submerged Aquatic Vegetation) Distribution in the Choptank River Basin



Benthic Community

The benthic community forms an integral part of the ecosystem in estuarine systems. For example, small worms and crustaceans are key food items for crabs and demersal fish, such as spot and croaker. Suspension feeders that live in the sediments, such as clams, can be extremely important in removing excess algae from the water column. Benthic macroinvertebrates are reliable and sensitive indicators of estuarine habitat quality.

Benthic monitoring includes both probability-based sampling (sampling sites are selected at random) and fixed station sampling (the same site is sampled every year). A benthic index of biotic integrity (B-IBI) is determined for each site (based on abundance, species diversity, etc.). The B-IBI serves as a single-number indicator of benthic community health. For a more details on the methods used in the benthic monitoring program see http://esm.versar.com/Vcb/Benthos/backgrou.htm

Overall, the Choptank River had good benthic community condition during the period 1994-2000. However, some degradation was noted in the mesohaline portion of the estuary. Fifty-seven percent of the samples collected in the lower mesohaline estuary failed to meet the Restoration Goals, but half of these samples were only mildly degraded, resulting in an overall low probability of observing degraded benthos (<35 percent, Figure CH17). Degradation in the lower mesohaline portion of the estuary was due primarily to low biomass, and secondarily to low abundance and numerical dominance of pollution-indicative species. A long-term benthic monitoring station (Sta. 64, Figure CH18) indicated marginal degradation with no significant trend in the B-IBI. An earlier improving trend at this station disappeared with the addition of the 2000 data.

Degradation in the upper mesohaline portion of the estuary exhibited a different pattern. Most failing sites were located upstream in the Cabin Creek area. Degradation was moderate to severe, and it was due to excess abundance and biomass at three sites. This type of condition is commonly associated with nutrient enrichment, and is consistent with observations of poor water clarity and nutrient-rich conditions in this region of the river. Dissolved oxygen conditions at time of sampling were good throughout the river.

Benthic community condition was best in the oligohaline portion of the Choptank River, with only two sites exhibiting mild degradation in benthic community measures (Figure CH17). However, uncertainty in the data was high, with a probability of observing benthos of indeterminate quality of 67 percent (Figure CH17). A long-term monitoring station (Sta. 66, Figure CH17) indicated good benthic community status with no significant trend in the B-IBI.

Figure CH17. Number of sites failing the B-IBI, probabilities and standard errors (SE) of observing degraded benthos, non-degraded benthos, or benthos of intermediate condition (indeterminate for oligohaline and low mesohaline habitats) for Choptank River Basin segments, 1994-2000. Probabilities (for all segments) and standard errors (for segments with ≥5 samples) were adjusted according to Agresti and Caffo (2000). Standard errors were used to calculate 67 percent (±SE) and 90 percent (±1.65 x SE) confidence limits. Exact confidence limits were used for segments with <5 samples, and are not shown in the tables. Adjusted probabilities do not add to 100 percent. Segment codes: OH = oligohaline, MH = mesohaline.

Segment	River	Number of Sites	Sites with B-IBI<3.0	P Deg.	P Non-deg.	P Interm.
CHOOH	Choptank	8	2	16.7 (10.8)	33.3 (13.6)	66.7 (13.6)
CHOMH2	Choptank	19	6	30.4 (9.6)	43.5 (10.3)	34.8 (9.9)
CHOMH1	Choptank	14	8	33.3 (11.1)	44.4 (11.7)	33.3 (11.1)

Figure CH18. Trends in benthic community condition at Choptank River Basin long-term monitoring stations, 1985-2000. Trends were identified using the van Belle and Hughes (1984) procedure. Current mean B-IBI and condition are based on 1998-2000 values. Initial mean B-IBI and condition are based on 1985-1987 values. NS: not significant.

Station[1]	Trend Significance	Median Slope (B-IBI units/yr)	Current Condition (1998-2000)	Initial Condition (1985-1987)
66 Choptank	NS	0.00	3.11 (Meets Goal)	3.03 (Meets Goal)
64 Choptank	NS	0.03	2.96 (Marginal)	2.65 (Marginal)

[1]Sta. 66 upper Choptank, oligohaline habitat, 38.801447 lat., 75.921825 long.
Sta. 64 lower Choptank, high mesohaline mud habitat, 38.590464 lat., 76.069340 long.

Nutrient Limitation

Like all plants, phytoplankton need nitrogen, phosphorus, light, and suitable water temperatures to grow. If light is adequate and the water temperature is appropriate, phytoplankton will continue to grow as long as unlimited amounts of nutrients are available. If nutrients are not unlimited, then the ratio of nitrogen to phosphorus affects phytoplankton growth. (Phytoplankton generally use nitrogen and phosphorus at a ratio of 16:1, that is, 16 times as much nitrogen is needed as phosphorus. This is called the Redfield ratio.) If one of the nutrients is not available in the adequate quantity, phytoplankton growth is 'limited' by that nutrient. If both nutrients are available in enough excess (regardless of the relative proportion of them) that the phytoplankton can not use them all even when they are growing as fast as they can under the existing temperature and light conditions, then the system is 'nutrient saturated.'

Nitrogen limitation occurs when there is insufficient nitrogen, i.e., there is excess phosphorus. Nitrogen limitation often happens in the summer and fall after stormwater flows are lower (so less nitrogen is being added to the water) and some of the nitrogen has already been used up by phytoplankton growth during the spring. If an area is nitrogen limited, then adding nitrogen will increase phytoplankton growth.

Phosphorus limitation occurs when there is insufficient phosphorus, i.e. there is excess nitrogen. If an area is phosphorus limited, then adding phosphorus will increase phytoplankton growth. Phosphorus limitation occurs in some locations in the spring when large amounts of nitrogen are added to the estuary from stormwater flow.

If an area is nutrient saturated, then both nitrogen and phosphorus are available in excess. In this case, if phytoplankton are exposed to appropriate water temperatures and sufficient light, they will grow. If an area is both nitrogen and phosphorus limited, then both nitrogen and phosphorus must be added to increase algal growth.

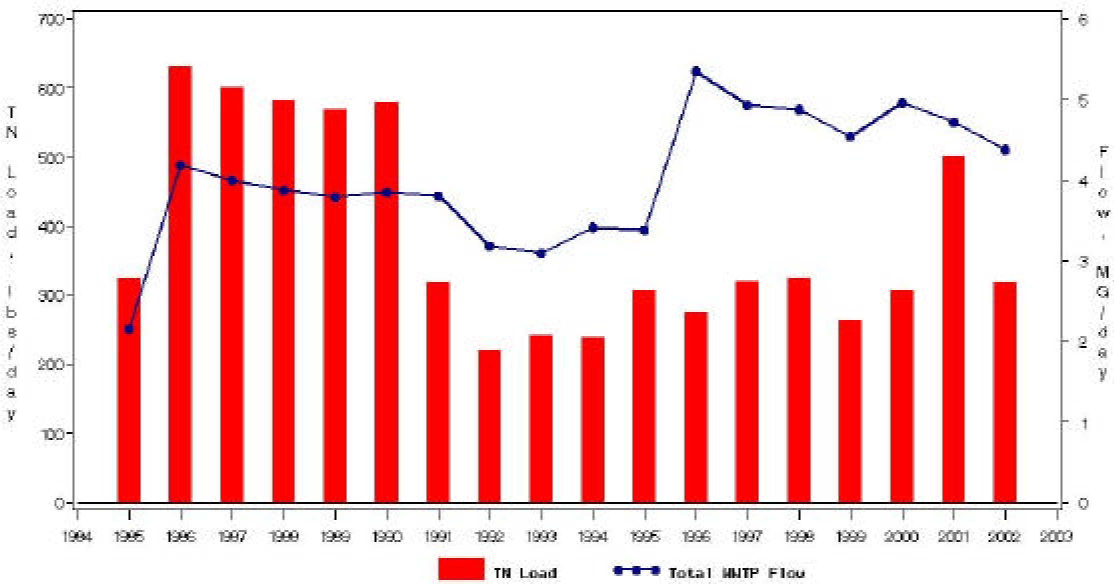
Managers can use the nutrient limitation model to predict which nutrient is limiting at a given location and use the information to assess what management approach might be the most effective for controlling excess phytoplankton growth. If an area is phosphorus limited, then reducing phosphorus will bring the most immediate reductions in phytoplankton grown. However, if nitrogen levels are not also reduced, the excess nitrogen that goes unused can be exported downstream. This excess nitrogen may reach an area that is nitrogen limited, fueling phytoplankton growth in that downstream area.

The nutrient limitation predictions are a valuable tool, but they must be used in conjunction with other water quality and watershed information to fully assess and evaluate the best management approach.

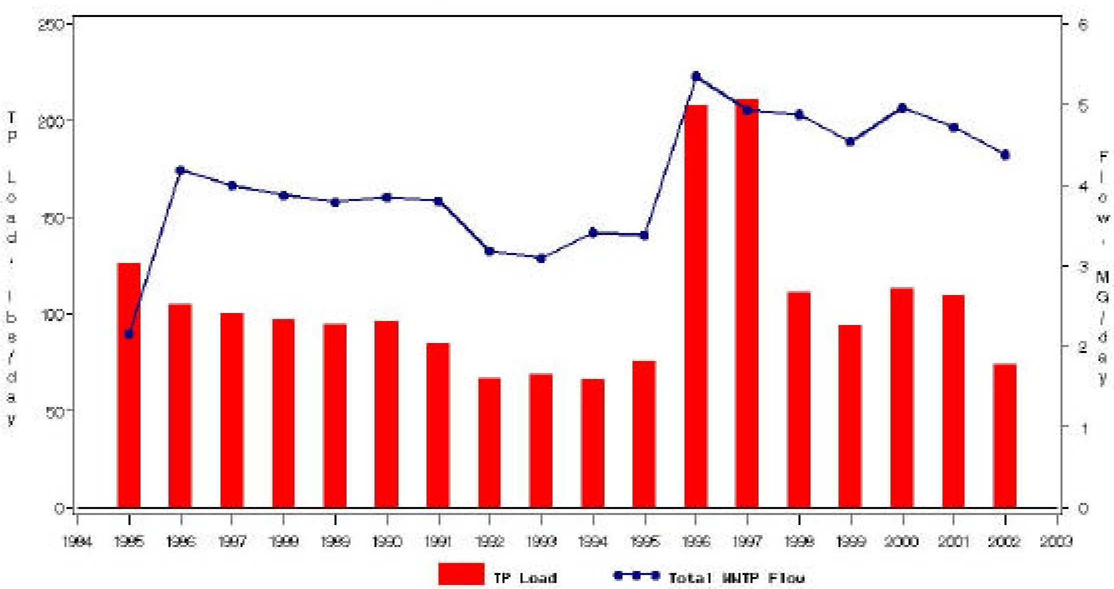
The nutrient limitation model was used to predict nutrient limitation for the four stations in the Choptank Basin. Results for each station are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). The upper Choptank station is nutrient saturated throughout the year. The other Choptank stations tend to be largely phosphorus limited in the spring, and largely nitrogen limited in summer and fall. See Appendix B for details.

Appendix A – Nutrient Loadings from Major Wastewater Treatment Facilities in the Choptank River Basin

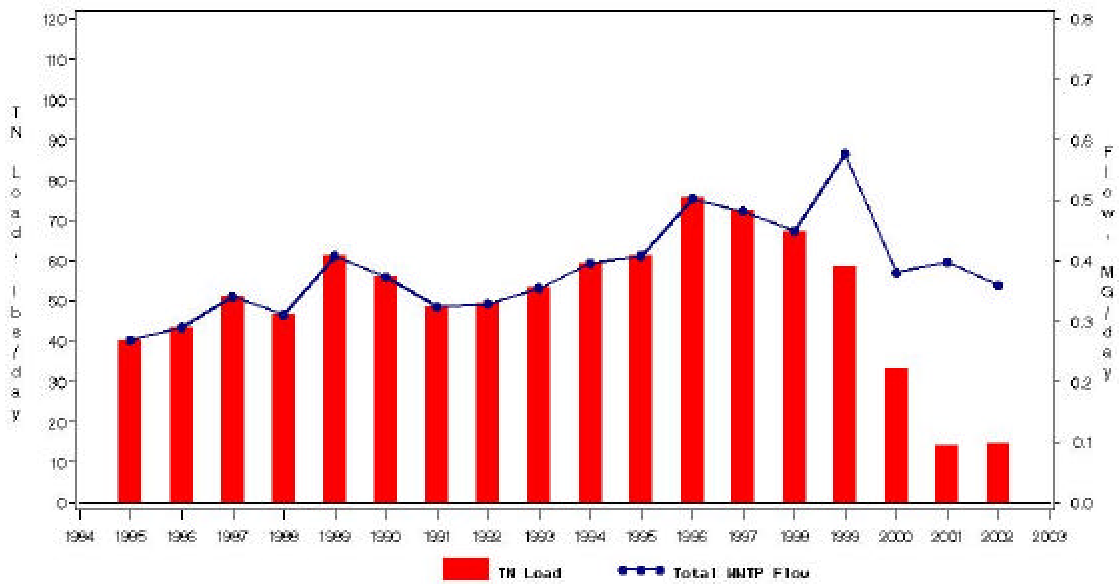
CAMBRIDGE Wastewater Treatment Plant: Choptank Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



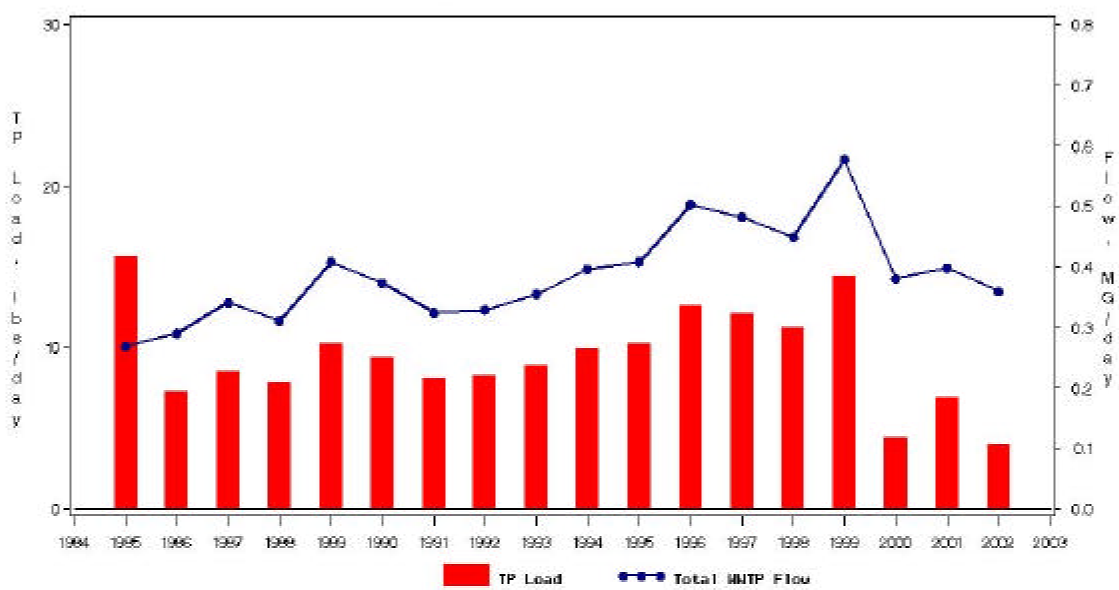
CAMBRIDGE Wastewater Treatment Plant: Choptank Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow

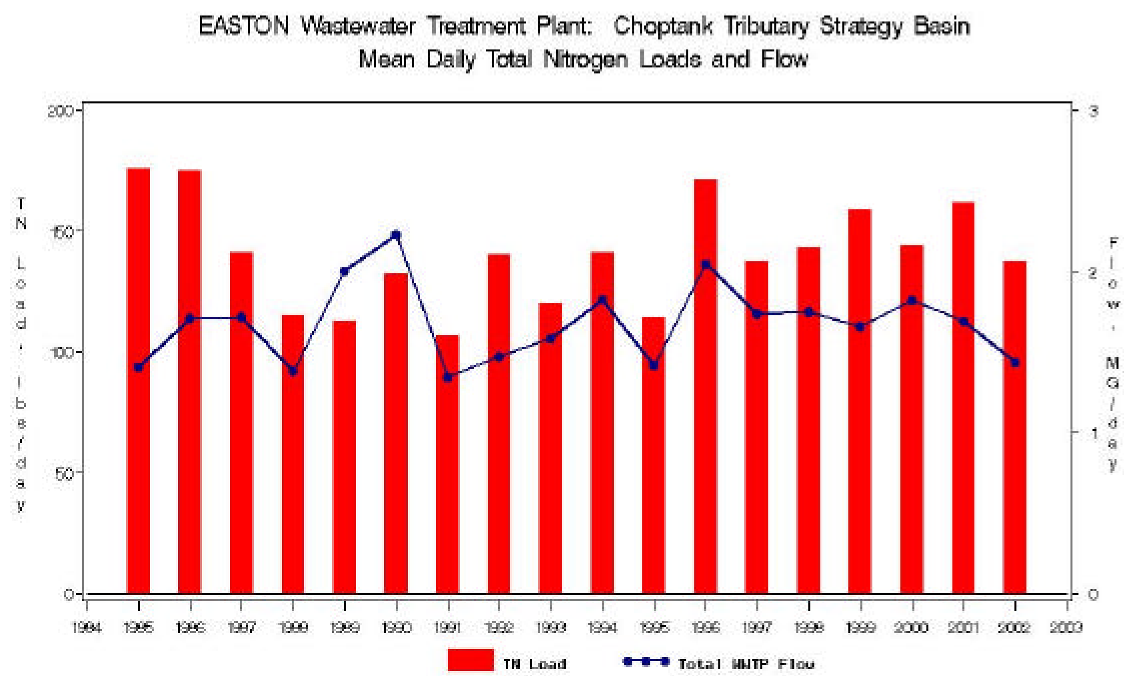


DENTON Wastewater Treatment Plant: Choptank Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow

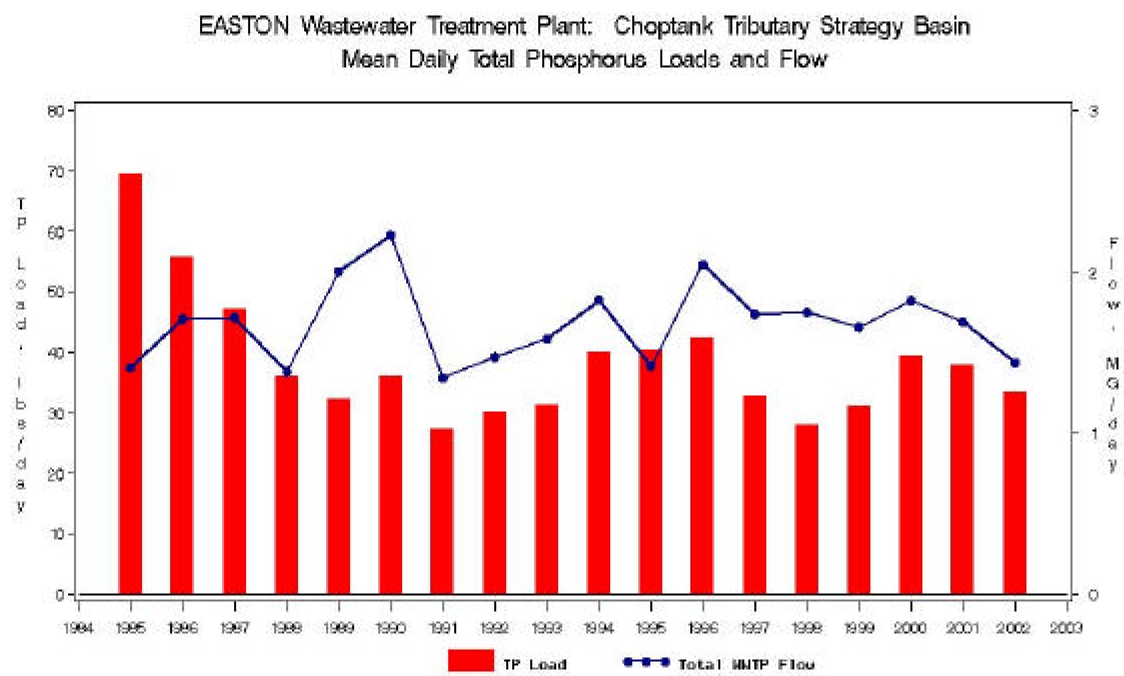


DENTON Wastewater Treatment Plant: Choptank Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow





EASTON Wastewater Treatment Plant: Choptank Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow
TN Load, lbs/day
Flow, MG/day
TN Load
Total WWTP Flow



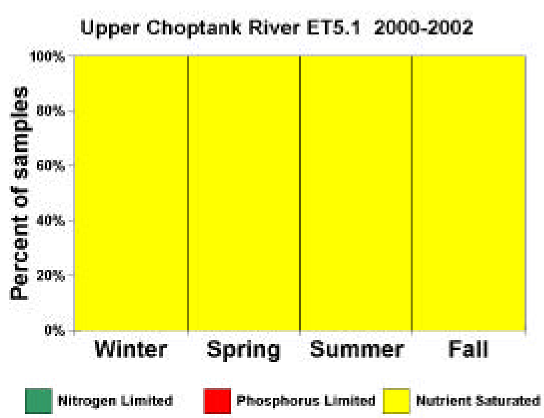
EASTON Wastewater Treatment Plant: Choptank Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow
TP Load, lbs/day
Flow, MG/day
TP Load
Total WWTP Flow

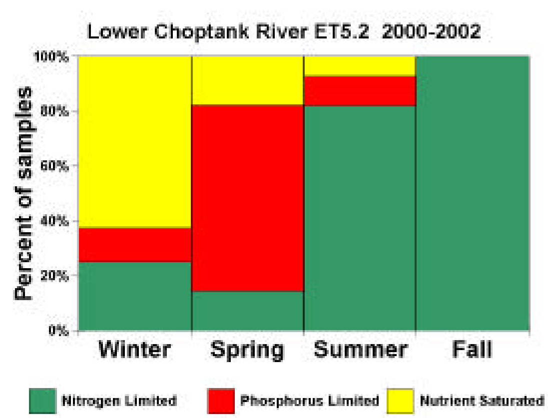
Appendix B – Nutrient Limitation Graphs for the Choptank River Basin

The nutrient limitation model was used to predict nutrient limitation for the four stations in the Choptank Basin. Results for each station are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). The upper Choptank station is nutrient saturated throughout the year. The other Choptank stations tend to be largely phosphorus limited in the spring, and largely nitrogen limited in summer and fall.

Managers can use these predictions to assess what management approach will be the most effective for controlling excess phytoplankton growth. Interpreting the results can be a little counter-intuitive, however. Remember that nitrogen limited means that *phosphorus* is in excess. Initially, it would seem that the best management strategy would be to reduce phosphorus inputs. However, it may actually be more cost effective to further reduce *nitrogen* inputs to increase the amount of 'unbalance' in the relative proportions of nutrients so that phytoplankton growth is even more limited. When used along with other information available from the water quality and watershed management programs, these predictions will allow managers to make more cost-effective management decisions.

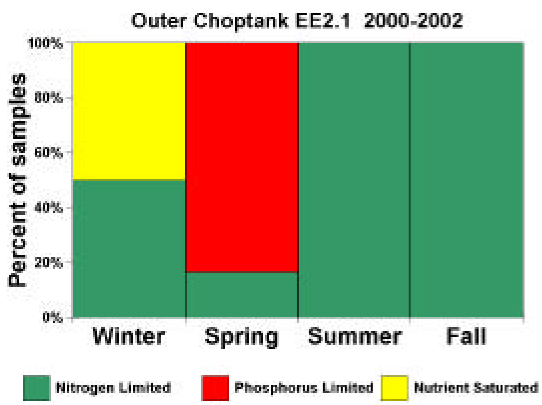
Middle Choptank (ET5.1) - Phytoplankton growth is entirely nutrient saturated (light limited or no limitation) at this station. This pattern is typical of turbid, nutrient enriched areas where nutrient limitation occurs primarily in the warmer/low riverflow periods (Fisher and Gustafson 2002). Total nitrogen, dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations are poor and dissolved organic nitrogen concentration is degrading (increasing), but total phosphorus concentration is fair and improving (decreasing). Reductions in nitrogen concentrations in the summer and fall may allow for nitrogen limitation during that portion of the year, but reductions in phosphorus are necessary in the winter and spring to reduce phytoplankton growth when dissolved nitrogen concentration is at the annual high.

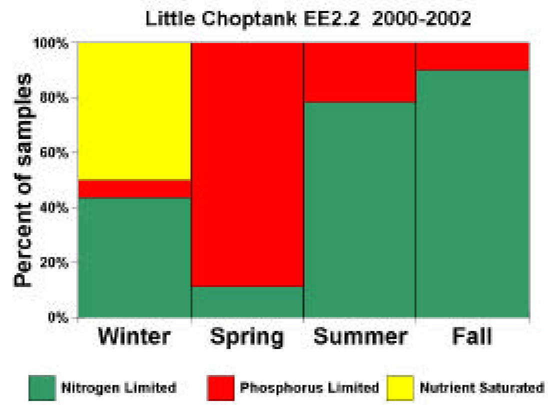




Lower Choptank (ET5.2) - On an annual basis, phytoplankton growth is nitrogen limited about 50% of the time. In the winter, phytoplankton growth is nutrient saturated (light limited or no limitation) about 60% of the time, and nitrogen or phosphorus limited 25% and 12% of the time, respectively. In the spring growth is phosphorus limited more than 65% of the time and nitrogen limited approximately 15% of the time. In the summer, growth is mostly nitrogen limited (more than 80% of the time) and sometimes phosphorus limited (10% of the time). In the fall, phytoplankton growth at this location is always nitrogen limited. This is typical of mesohaline areas, where river discharge dictates a seasonal pattern of limitation due to low light/temperatures in winter, high dissolved inorganic nitrogen/dissolved inorganic phosphorus in high river discharge in the spring, large fluxes of dissolved inorganic phosphorus fluxes from the sediments under anoxic conditions in the summer, and turnover of the water column in the fall (Fisher and Gustafson 2002). Ratios of nitrogen to phosphorus are relatively high in winter and very low in summer and fall. Total nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are relatively fair; dissolved organic nitrogen concentration is relatively good. Dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations are also improving (decreasing). This suggests that reductions in both nitrogen and phosphorus would reduce phytoplankton growth and removing even a little additional phosphorus in the spring may help to further limit phytoplankton growth in that key season.

Outer Choptank (EE2.1) - On an annual basis, phytoplankton growth is nitrogen limited 60% of the time and phosphorus limited 25% of the time. In winter, phytoplankton growth is either nitrogen limited (50%) or nutrient saturated (light limited or no limitation). In the spring, phytoplankton growth is phosphorus limited approximately 85% of the time and nitrogen limited approximately 15% of the time. In summer and fall, growth is entirely nitrogen limited. This is typical of mesohaline areas, where river discharge dictates a seasonal pattern of limitation due to low light/temperatures in winter, high dissolved inorganic nitrogen/dissolved inorganic phosphorus in high river discharge in the spring, large fluxes of dissolved inorganic phosphorus fluxes from the sediments under anoxic conditions in the summer, and turnover of the water column in the fall (Fisher and Gustafson 2002). Total nitrogen, dissolved inorganic nitrogen, and total phosphorus concentrations are relatively good and all are improving (decreasing); dissolved inorganic phosphorus concentration is also relatively good. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively low in the spring (but nitrogen is still in excess). Further reductions in phosphorus in the winter and spring will increase the occurrences of phosphorus limitation and further limit phytoplankton growth. Further reductions in nitrogen will also help bring the system into better balance and further limit phytoplankton growth in the summer, fall and winter.





Little Choptank (EE2.2) - On an annual basis, phytoplankton growth is nitrogen limited about 50% of the time and phosphorus limited about 35% of the time. In winter, phytoplankton growth is nitrogen limited (about 45%) or nutrient saturated (light limited or no limitation, 50% of the time). In the spring, phytoplankton growth is phosphorus limited approximately 90% of the time and nitrogen limited approximately 10% of the time. In summer, growth is nitrogen limited almost 80% of the time and phosphorus limited about 20% of the time. In the fall, growth is nitrogen limited 90% of the time and phosphorus limited 10% of the time. This is typical of mesohaline areas, where river discharge dictates a seasonal pattern of limitation due to low light/temperatures in winter, high dissolved inorganic nitrogen/dissolved inorganic phosphorus in high river discharge in the spring, large fluxes of dissolved inorganic phosphorus fluxes from the sediments under anoxic conditions in the summer, and turnover of the water column in the fall (Fisher and Gustafson 2002). Total nitrogen, dissolved inorganic nitrogen, and dissolved inorganic phosphorus concentrations are all good and all are improving (decreasing); total phosphorus concentration is relatively good. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively low (but nitrogen is still in excess), indicating that reductions in nitrogen will enhance limitation. Reductions in phosphorus in the winter and spring will increase the occurrences of phosphorus limitation and further limit phytoplankton growth. Further reductions in nitrogen will also help bring the system into better balance and further limit phytoplankton growth in the summer, fall and winter.

Appendix C – References

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